10/527953
DT12 Rec'd PCT/PTO 14 MAR 2005

Structural Component made of Fibre-reinforced Thermoplastic Material

The invention is related to a structural component made of long-fibre reinforced thermoplastic material with integrated continuous fibre reinforcements according to the generic term of claim 1.

Known structural components of this kind in most instances comprise plane continuous fibre reinforcements, e.g., with semi-finished fabric products or with a sandwich structure, which, however, are very limited with respect to possible shapings and applications. Structural components with integrated continuous fibre strands have also become known. WO99/52703 discloses a structural component with a shape forming long-fibre reinforced thermoplastic matrix and with an integrated load-bearing structure made of continuous fibre strands. In this, the continuous fibre strands are joined to one another by plane junction points. This, however, solely results in simple, plane load-bearing structures and not in three-dimensionally shaped continuous fibre reinforcement structures for the optimum absorption and transmission of three-dimensionally attacking loads and forces.

It is therefore the objective of the invention presented here to overcome the disadvantages and limitations of the known structural components and to create a structural component with a light continuous fibre reinforcement structure, which makes possible a three-dimensional supporting and transmission of loads and forces to be absorbed, with an optimum adaptation to the force gradients for a broad range of applications.

This objective is achieved in accordance with the invention by a structural component according to claim 1, with an integrated three-dimensional intersection point, which is

formed out of several individual, shaped continuous fibre (EF) - profiles in a long-fibre thermoplastic (LFT) - mass.

The dependent claims relate to advantageous further developments of the invention with respect to optimum three-dimensional design of the continuous fibre reinforcement structure and utilisability in a large number of applications with optimum mechanical characteristics for the absorption of loads in any direction. This results in light, easy-to-manufacture structural components, e.g., for means of transportation, vehicles and vehicle components with load-bearing functions.

In the following the invention is further explained on the basis of examples of embodiments and Figures. These illustrate:

Fig. 1a	a structural component according to the invention with a three-dimensional intersection point of several EF - profiles,
Fig. 1b, c	cross-sections through a three-dimensional intersection point in different views,
Fig. 2	a further example of a three-dimensional intersection point with variable profile cross-sections,
Fig. 3a	an "X" - shaped intersection point,
Fig. 3b	a "T" - shaped intersection point,
Fig. 3c	an "L" - shaped intersection point,
Fig. 4	a "T" or "X" - shaped moment load-lever structure,
Fig. 5	an "L" - shaped moment load-lever structure,
Fig. 6	examples of three-dimensional profile shapings,
Fig. 7a, b	two different cross-sectional shapes of an EF - profile in a rib,
Fig. 8a	an arrangement of several EF - profiles in a 2/3 rear seat back with three-dimensional intersection point,
Fig. 8b	the LFT - shaping of the component with the integrated EF - profiles,
Fig. 9	a single seat back with three-dimensional intersection points,
Fig. 10	an arrangement of EF - profiles as seat shell or cabin floor,
Fig. 11	a car door structure,

Fig. 12 an example of a two-shell component.

Fig. 1a illustrates a structural component according to the invention with a three-dimensional (spatial) intersection point 50. The structural component comprises a shaping LFT - mass 6 (made of long-fibre reinforced thermoplastic) with a continuous fibre reinforcement comprising several individual, integrated EF - profiles 10 with a defined shaping, which are shaped corresponding to the forces and loads to be absorbed and are arranged within the structural component individually precisely positioned. The three-dimensional intersection point 50 comprises an upper and a lower main plane H1, H2 with a vertical spacing v. It is formed by at least three EF - profiles, which run together, resp., intersect with one another at the intersection point, and by the LFT - mass 6 joining all these profiles. In this, at least one EF - profile respectively has to lie in the upper main plane H1 (here the profile 10.1) and one EF - profile in the lower main plane H2 (here the profile 10.4). And between the EF - profiles of the upper and of the lower main plane at least one further EF - profile, here the profiles 10.2 and 10.3, with a vertical orientation, resp., with an extension in vertical direction, has to pass through, in order to absorb a moment M2. All EF - profiles are joined together at the intersection point by the LFT – mass 6 in a force transmitting manner (UB) through corresponding shapings 32 of the LFT - mass, resp., through a mutual matching to one another with respect to shape of the EF - profiles and of the LFT - mass.
In the example of Fig. 1a the EF - profiles 10.1, 10.4 are located in a crimp 7 and the EF - profiles 10.2 and 10.3 in ribs 8. In this manner forces F, moments M and loads L, which act on a structural component in differing directions, are absorbed by the EF - profiles and transmitted to the three-dimensional intersection point 50. It is in particular possible to transmit moments at the intersection point from one profile pair to the other one. Here the EF - profiles 10.1 and 10.4 with the crimp 7 form a girder subject to bending and the profile pairs 10.2 and 10.3 in the rib structure 8 form a second girder subject to bending. With this, e.g., the moments M1 and M2 are absorbed and each respectively transmitted. An essential advantage of this arrangement of the EF - profiles according to the invention at the three-dimensional intersection point is the fact, that it consists of a single component and does not have to be assembled out of several

components. For this purpose, according to the example the EF - profiles may be inserted into an LFT - shaping tool one after the other or together and subsequently together with an introduced, molten LFT - mass in a single step be pressed to become a one-part structural component in an LFT - press.

The sequence of depositing here is the following: First the EF - profile 10.1 is deposited in the lower main plane H2, then the EF - profiles 10.2 and 10.3 in the vertical intermediate zone v and thereupon the EF - profile 10.4 in the upper main plane H1 and subsequently the molten LFT - mass is placed on top and pressed together with the EF - profiles. This Fig. 1a illustrates a component, which following the pressing in the LFT - tool was turned over, so that in the figure H1 lies at the bottom and H2 lies on top. This way the EF - profiles are well visible. The direction, in which the EF - profiles 10 and the LFT - mass 6 are deposited, is indicated with an arrow.

The Figs. 1b, 1c illustrate two sections through a further example of a three-dimensional intersection point 50 with two EF - profiles 10.3, 10.4 in the upper main plane H1, an EF - profile 10.1 in the lower main plane H2 as well as an EF - profile 10.2 in a rib 8 in the vertical zone v in between. The EF - profiles 10.1, 10.3, 10.4 are lying in a crimp 7, which intersects with the rib 8. The position of the component here is illustrated in the manner it lies in the LFT - tool.
Fig. 1b illustrates the cross-section through the crimp 7, (which absorbs the moment M1) and Fig. 1c the cross-section through the rib 8, (which absorbs the moment M2).

For the optimum force transmission of EF - profiles 10 on to the LFT - mass 6 and from an EF - profile (10.1) through the LFT - mass on to other EF - profiles (10.3, 10.4), the LFT - mass comprises bonding shapings 32. By the arrangement of the EF - profiles and the shapings 32 of the LFT - mass the required force transmission UB is produced at the three-dimensional intersection point 50.

Fig. 2 illustrates a further example of a three-dimensional intersection point in a component, which is designed as a bent shell. The main planes H1 and H2 here form

tangential planes at the intersection point 50. The given possible vertical spacing between H1 and H2 shall be relatively small for reasons of space. Then the EF - profile 10.2 intersecting with the flat EF - profiles 10.1 and 10.3 in the zone v at the intersection point is able to comprise a reduced height with, e.g., a square cross-section a and adjacent to the intersection point 50 once again change over into a flat, vertically oriented cross-section b. Important is the fact, that the EF - profiles in the v - zone comprise a vertical extension for the purpose of transmission of moments. I.e., the EF - profiles 10 in principle are able to comprise any three-dimensional shaping and position, which is optimally adapted to the load conditions and the force gradients.

The Figs. 3a, b, c schematically illustrate various possible types of three-dimensional intersection points. Demanding structural components have to absorb and to transmit onwards several loads L, forces F and moments M, which attack at different points of the structural component and in differing directions. The three-dimensional intersection points 50 according to the invention for this purpose by means of corresponding arrangements of the EF - profiles in principle are able to be, for example, designed as "X"-, "T"- or "L"-shaped.

Fig. 3a in this context illustrates an "X"-shaped intersection point with load absorptions at the points L1 to L4 and with the force transmissions UB at the intersection point 50.

Fig. 3b illustrates a "T"-shaped intersection point with load absorptions at the points L1, L2, and L3 and with the force transmissions UB at the intersection point.

Fig. 3c illustrates an "L"-shaped intersection point with the load absorptions L1, L2, L3 and at the point L2 also with the force transmissions UB at the intersection point.

The Figs. 4, 5 illustrate examples of moment - load lever structures, which are formed by the arrangement of the EF - profiles with the intersection point 50.

Fig. 4 illustrates a moment - load lever structure with a "T"- or "X"-shaped intersection point 50. With it a force +F is supported as main load direction and absorbed by an EF - profile 10.2 as vertically oriented profile v, e.g., in a rib between two horizontal EF - profiles 10.1 in the lower main plane H2 and 10.3 in the upper main plane H1. The force F results in a moment M, which is supported by the EF - profiles 10.1, 10.3 in an appropriate shaping of the LFT - tool, e.g., in a crimp.

Fig. 5 illustrates an "L"-shaped moment - load lever structure, which as main load directions supports forces +F, -F (i.e., in both directions). It once again contains a vertically oriented profile 10.2 in the zone v, which is supported by three EF - profiles, e.g., at a crimp and in the main planes: the EF - profile 10.1 in H2 and the EF - profiles 10.3 and 10.4 in H1. With this, the moments +M, -M resulting from the forces +F, -F are supported and transmitted onwards.

With their shaping, the EF - profiles correspond to the differing functions and requirements at different points of an EF - profile, resp., component. They may comprise a three-dimensional shaping and for this purpose in longitudinal direction comprise a bend, a rotation, a twisting, a folding and/or a surface structuring and they may comprise varying, differing cross-sectional shapes.

Fig. 6 illustrates examples of possible shapings of this kind of the EF - profiles:

- The EF - profile 10.1 manifests a roundish cross-section, which is flattened and spread out and there forms a large bonding surface to the surrounding LFT - mass (in the same manner as EF - profile 10.5).
- The EF - profile 10.2 comprises a flat arc and is split in two at one end.
- The EF - profile 10.3 comprises a twist from a flat to a vertically oriented cross-section.
- The EF - profile 10.4 manifests a fold and
- The EF - profile 10.5 a structured, zig-zag-shaped and through this enlarged surface.
- The EF - profile 10.6 is bent into a "U"-shaped double rib. This could be utilised, e.g., in place of the two EF - profiles 10.2 and 10.3 in Fig. 1a.

The Figures 7a, 7b illustrate an example of an EF - profile 10, which over its length comprises differing cross-sectional shapes, this in adaptation to the forces to be transmitted and for the optimum bonding with the LFT - mass 6. The Figures in cross-sectional view illustrate an EF - profile 10a, 10b in a rib 8, e.g., corresponding to the profiles 10.2 or 10.3 of Fig. 8, at two different locations.

Fig. 7a illustrates a shaping 10a with a positioning shoulder 55 for fixing and holding the EF - profile in the required position - this especially during pressing, when the liquid LFT – mass 6 is pressed into the rib. On top and underneath the EF - profile respectively comprises a thicker zone 56 as tensile - and compressive zones (in longitudinal fibre direction) for the transmission of moments. Located in between is a thinner thrust zone 57 with a correspondingly thicker adjacent LFT - layer 6 and with a large bonding surface area and a particularly strong interface joint. With this, the shear resistance is increased by the adjacent LFT - layer 6 with isotropic fibre distribution (while the strength transverse to the fibre orientation in the EF - profiles 10 here is lower).

At another location according to Fig. 7b the profile cross-section 10b is changed corresponding to the force situation there: stretched, i.e., higher and narrower and without a positioning shoulder.
For the secure and accurate positioning and fixing of the EF - profiles, this also during the pressing with the LFT - mass, further positioning points 54 may be developed on the EF - profiles, which correspond to the shaping of the LFT - tool 31o (top) and 31u (bottom). Here the positioning point 54 serves for the accurate positioning below in the rib 8. Positioning points can also be arranged suitably distributed in the longitudinal direction of the EF - profiles.

In an analogous manner, profile shapes of this kind may also be positioned and fixed on crimped walls, e.g. on the two side walls of a crimp 7 instead of the two EF - profiles (10.2., 10.3) in two separate ribs 8, as it is illustrated in the following example of Fig. 8.

Instead of the examples 7a, 7b, it is also possible to design the cross-sections of EF - profiles, for example, as "L"- or "Z"-shaped, depending on the application.

Figs. 8a, b illustrate the example of a complex structural component with a three-dimensional intersection point in the form of a two third (2/3) rear seat back 74 with a central seat belt connection 60 for the middle seat and a lock 58 and with several demanding load introductions for different load cases (crash loads). Fig. 8a in plan projection illustrates the arrangement of the EF - profiles in the component and Fig. 8b in a perspective view the LFT - mass 6 and drawn in it the integrated EF - profiles 10.1 to 10.4. This example illustrates the load-optimised shaping of the EF - profiles themselves as well as the load-optimised arrangement to form a structure with a corresponding shaping of the LFT - mass 6 and with an optimum bonding strength between the EF - profiles carrying the main loads (with directed continuous fibres) and the complementing LFT - mass (with undirected long fibres).

Here four main load carrying points L1 to L4 result from:

- the loads L1, L2 on the axle holders 59a, 59b, around which the rear seat back 74 is capable of being swivelled,
- the load L3 on the lock 58, for fixing the rear seat back in its normal position and
- the load L4 on the belt lock, resp., belt roller 60 for the central belt of the middle seat.

With this structural component the following load cases (with the further loads L5 to L9) are covered:

- Front - and rear collision
- Securing of any goods loaded
- Belt anchoring
- Head support / head rest anchoring.

For the receiving and transferring of all loads and forces the intersecting EF - profiles together with the joining force-transmitting shapings of the LFT - mass form a spatial,

three-dimensional intersection structure 50. Here the EF - profiles respectively in pairs in the LFT – shapings form a moment-transmitting girder subject to bending:

– The EF - profiles 10.1 and 10.4 in a crimp 7 of the LFT – mass form a girder subject to bending between the loads L1 and L4
– and the EF - profiles 10.2 and 10.3 in the ribs 8 of the LFT - mass a girder subject to bending between the loads L2 and L3.

Through the three-dimensional intersection point 50, in this the load L4 on the belt roller 60 and also other loads, which act on the girder subject to bending 10.1 / 10.4, is also supported on the other girder subject to bending 10.2/ 10.3 (and vice-versa).

The main forces, resp., loads L1 to L4 are received by means of force introduction points:

– through shapings 22 and 32 of the EF - profile ends and of the LFT - mass for receiving the external forces with or without inserts 4.
– In doing so, the inserts 4 prior to the pressing operation are able to be inserted into the LFT - tool and then pressed together with the EF - profiles and the LFT mass
– or else it is also possible to fit them into the component later on.

Here the EF - profile 10.1 comprises an arc-shaped widening 22 and an adapted widening 32.1 for receiving a metallic insert 4 at the axle bearing 59a. The other axle holder receptacle 59b is formed by shapings 22.2 of the EF - profiles 10.2 and 10.3 and by adapted joining shapings 32.2 of the LFT - mass. These profile ends 22.2 are bent over and in this manner anchored in the LFT - mass for the purpose of increasing the tensile strength. The lock 58 is bolted on to a lock plate on the EF - profile 10.3 and supported by the EF - profile 10.2. The belt roller 60 is supported by shapings 22 of the EF - profiles 10.1 and 10.4 and by LFT - shapings 32.
The smaller loads L8, L9 of head supports 61 here are absorbed through LFT - shapings 32. For reinforcement, however, it would also be possible to integrate an additional EF - profile 10.5 deposited transversely (in some zones oriented flat or vertically).

The depositing sequence of the EF - profiles into the LFT - tool is as follows:
First the EF - profile 10.1 (in H2), thereupon the EF - profiles 10.2 and 10.3 and subsequently the EF - profile 10.4 (in H1). Then the liquid LFT - mass 6 is introduced and the complete tool pressed as a single shell and as a single part in a single step. (The illustrated structural component is lying in the LFT - shaping tool upside down, i.e., there H2 is at the bottom and H1 is on top. Fig. 8 illustrates the rear side of the rear seat back 74.)
In this example also the three-dimensional profile shaping is evident in many variants.

The shapings in the structural component may comprise special shapings 22 for force transmissions and for the direct absorption of external loads, resp., for the receiving of inserts 4 (mounting parts), at which external loads are introduced into the component. The shaping of the surrounding LFT - mass 6 is also selected to match the shaping of the EF - profiles 10. Shapings of force transfer points (of forces and moments) inside a component (e.g., from an EF - profile through the LFT - mass on to other EF - profiles) can be formed both as shapings 22 of the EF - profiles as well as shapings 32 of the LFT - mass.
In general as balanced as possible, continuous transitions are formed for the reduction of steps in strength and rigidity between the EF - profiles and the LFT - mass.

Fig. 9 illustrates a single seat back 72 with a belt connection 60 and head supports 61, in the case of which similar loads and load cases occur as in the example of Fig. 8, here with the main loads L1 at the belt connection 60 and L2 with the weight of the passenger. All loads, however, have to be supported by the axle holders, which are capable of being fixed 59b, and possibly also 59a, around which the seat back is adjusted as capable of being swivelled. In this, the locking may be present on both sides on 59b and 59a or frequently only on one side on 59b. In the latter case, a profile support formed out of EF - profiles between the lock 59b and the belt connection 60 has to be designed to be particularly strong with an enhanced stiffness against torsion. For this purpose here a closed hollow profile cross-section can be formed (in analogy to Fig. 12), for example, with three EF - profiles 10.1, 10.2, 10.3 in a crimp 7 of the structural

component 1 and on it a separate cover component 1.2 with an EF - profile 10.10 may be thermoplastically welded on.

The profile support between the axle holders and the locks 59a and 59b here comprises the EF - profiles 10.4, 10.5, 10.6 in the main planes H1, H2 on a crimp 7. The profile support between the axle holder 59a and the belt connection (belt roller) 60 is curved and comprises two vertical EF - profiles 10.7, 10.8, e.g., in the side walls of a crimp 7. Here two three-dimensional intersection points 50 are formed on the axle holders 59a and 59b. In doing so, all EF - profiles are integrated into crimps here, wherein at the three-dimensional intersection points of the EF - profiles the crimps locally become ribs, so that there an intersection point between a rib 8 and a crimp 7 is always produced and so that all EF - profiles are capable of being deposited in a single step and the structural component 1 is able to be pressed in a single step and in a single piece. It goes without saying, that other arrangements of EF - profiles in ribs and in crimps are also able to be combined as per requirement.

Fig. 10 illustrates an arrangement of EF - profiles with a three-dimensional intersection point 50, which is designed as a seat shell 76 or as a cabin floor, e.g., of a lift cabin. In order here to implement a shell with a relatively small thickness, i.e., with a small vertical spacing v between the main planes H1, H2, in this case three vertical EF - profiles 10.2, 10.3, 10.4, are integrated into a rib structure, which intersect with two EF - profiles 10.1, 10.5 in the main planes H1, H2. At a free end L1 of a seat shell, the EF - profiles 10.1 und 10.5 may also run together and may be directly joined together there in a plane manner. With the loads L2 – L4 (also L1) this structure is supported.

Fig. 11 illustrates an example of a structural component, which forms a supporting structure of a car door 78 with integrated side crash protection. The EF - profile structure with a "T"-shaped intersection point 50 is formed by two girders with EF - profiles subject to bending running together at the intersection point, which, connect the force absorbing load points L1 and L2 = upper and lower door hinge 79a and 79b as well as L3 = door lock 80. The girder subject to bending a connects the upper hinge 79a

with the lock 80 and the girder subject to bending b the lower hinge 79b with the lock 80, wherein this latter one merges into the girder subject to bending a at the intersection point 50 and continues on up to the lock 80 (a + b). The arrangements of the EF - profiles 10.1, 10.4 of the girder subject to bending a in a crimp 7 and of the EF - profiles 10.2, 10.3 of the girder subject to bending b in the ribs 8 as well as the combination a + b with all four EF - profiles on the crimp 7 are depicted in cross-sectional views. This results in a strong and lightweight reinforcing structure, in order to, e.g., also be capable of absorbing and supporting side crash loads L4, L5.

Fig. 12 illustrates an example of a structural component 82, which is assembled out of several parts, e.g., out of two shells, e.g., by welding or by gluing. Here a structural component 1 with an intersection point is joined to a further component 1.2, which forms a cover to an open crimp, so that both components 1 and 1.2 together form a closed, tubular, EF - reinforced profile cross-section with particularly high stiffness against torsion (as is explained as a variant in Fig. 9). Two-part components of this kind are in preference welded together thermo-plastically. The shaping of the vertically oriented EF - profiles 10.2 and 10.3 in the side walls of the crimp 7 may, e.g., also comprise a flat part, which is adapted to the EF - profile 10.10 in the cover component 1.2. Behind these EF - profiles 10.2, 10.3 it would be possible, e.g., to form a three-dimensional intersection point 50 with a vertical EF - profile 10.4 running through transversely.

The following materials are suitable for the structural components according to the invention: The LFT - mass 6 advantageously comprises an average fibre length of at least 3 mm, even better of 5 – 15 mm. The continuous fibre (EF) reinforcement of the EF - profiles may consist of directed glass -, carbon - or aramide fibres in the thermoplastic matrix (wherein in special cases also boron fibres for the highest compressive strengths or steel fibres would not be excluded).

The EF - profiles 10 are capable of being mainly built-up out of UD (unidirectional) - layers (0°), also, however out of layers with differing fibre orientations, e.g., alternating

with layers of 0°/90° or 0°/+45°/-45° fibre orientations. They could possibly also comprise a thin surface layer (e.g., 0.1 – 0.2 mm) made of pure thermoplastic material without any EF - fibre reinforcements.

Especially suitable for structural components are partially crystalline polymers such as polypropylene (PP), polyethylene-therephtalate (PET), polybutylene-therephtalate (PBT) or polyamide (PA) as matrix of EF - profiles 10 and of LFT - mass 6, e.g., because these are capable of comprising higher compressive strengths. It is also possible, however, to utilise amorphous polymers such as ABS or PC.

Within the scope of this description, the following designations are used:

1	Structural component
1.2	Second part (two-shell)
4	Inserts, inlays
6	LFT - mass, form mass
7	Crimp
8	Rib
10	EF - profiles
22	EF - profile shapings
32	LFT - shapings
50	Three-dimensional intersection point
54	Positioning points
55	Positioning shoulder
56	Thick tensile - and compressive force zones in 10
57	Thinner thrust zone
58	Lock
59a, b	Axle holders
60	Belt roller, belt connection, belt lock
61	Head supports
72	Single seat
74	2/3 Rear seat back

76	Seat shell, cabin floor
78	Car door
79	Door hinges
80	Door lock
82	Two-shell structural component
LFT	Long-fibre thermoplastic
EF	Continuous fibre
H1	Upper main plane of 50
H2	Lower main plane of 50
v	Distance between H1 and H2 (vertical)
L	Loads (K, M)
F	Forces
M	Moments
UB	Force transmission at 50

"T"-, "L"-, "X"-shaped intersection point